HUMAN IMPACT AND SPONTANEOUS REGENERATION OF A KARST-AEOLIAN ECOSYSTEM IN AN ANTHROPOGENIC DESERT NEAR OLKUSZ (SILESIAN UPLAND, POLAND)

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Summary

The presence of thick, sandy, Quaternary cover sediments over Triassic and Jurassic carbonate rocks, with a well-defined karst-fissured aquifer, in the eastern part of the Silesian Upland (South Poland) has resulted in an unusual karst-aeolian environment. The occurrence and specific properties of karst water discharging within fluvio-glacial and aeolian sands created conditions for the development of unique floristic associations. However, intensive human activity, principally heavy industry and mining, changed the ecosystem. Archaeological and historical data indicate that ancient exploitation of lead ores began in the eastern part of Silesian Upland in the first millennium AD. Intensive exploitation and production of silver and lead in this karstic area is dated to the 13th century. In the early metallurgic works, charcoal was used as the basic fuel. Medieval deforestation of the Olkusz area was the main factor in the development of an anthropogenic sandy desert (the Bledow Desert) over the karst-fissured system. During the 16th and 17th centuries there was a second period of intensive deforestation of the area. The wood(oak and beach trees mainly) was used for charcoal production and for construction of underground and surface drainage canals. In that period, local artificial drainage was accompanied by total destruction of the ecosystem, with the exception of the unique karst spring ecosystems. With the introduction of coal as a fuel for industry in the 19th century the reforestation process began. In addition to huge dewatering of the karst-fissured aquifer and the chain of changes induced by man in the karst-aeolian environment due to contemporary lead and zinc ores exploitation, spontaneous regeneration of forest ecosystems is recorded. Utilisation of the Bledow Desert as an army polygon for several tens of years (mainly during and just after World War II) and a large fire in early 1990's interrupted 20th century spontaneous reforestation. This present a major problem for nature protection in the area, whether to protect a desert that is unique in Europe but whose aeolian landscape is an artefact of human activity and will need to be artificially maintained in the future or to permit the area to be overgrown by means of spontaneous succession, thereby protecting the karst-fissured aquifer.

Introduction

Evaluation of transformation stage and setting environmental protection strategy for karst areas are serious practical problems. This task is very complicated and more complex in areas of confined or semi-confined karst aquifers and in areas of buried karst with palaeokarstic features. In such areas it is difficult to identify zones exposed to human activity influencing transformation and destruction of all karst system. On the base of experiences from semi-confined, buried in Pleistocene sands and clays, affected by intensive human activity karst area of eastern Silesian Upland in South Poland as example, the authors remark complexity of interdependence between different components of the environment. Direct proximity and interactions between carbonate Triassic and Jurassic rocks and thick cover of Quaternary sediments result in an unusual karst-aeolian environment (*Fig. 1 and 2*). Sustained and intensive human activity in eastern Silesian Upland resulted in the development of an anthropogenic sandy desert (the Bledow Desert). This desert is the only sandy area with contemporary active aeolian processes in Central Europe. Now, the established desert ecosystems are in danger due to overgrowth and spontaneous regeneration of forest environments. It is necessary to emphasise that forest biocenoses are the climax for south Poland and without human support all the area will overgrow by trees. Hence, it has become a conflict of interests and dilemma for nature protection priority. The question is, whether to protect a desert that is unique in Europe but whose aeolian landscape is an artefact of human activity and will need to be artificially maintained in the future or to permit the area to be overgrown by spontaneous succession, thereby protecting the karst-fissured aquifer.

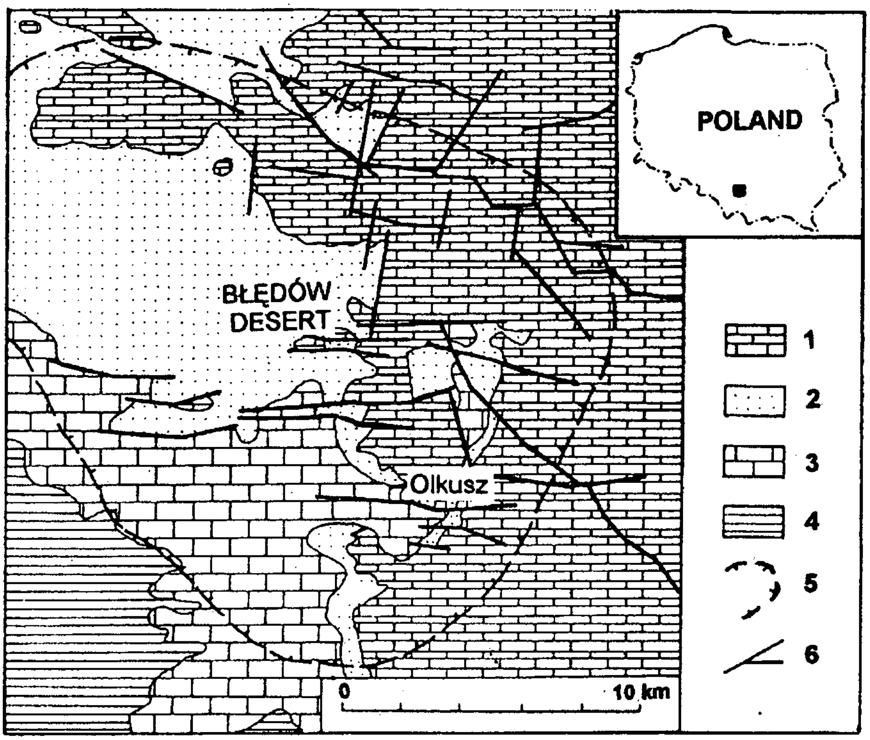

Fig. 1 Location and outline geology (without Quaternary sediments) of the Bledow Desert
1 - Upper Jurassic limestone; 2 - impermeable Upper Triassic and Lower Jurassic rocks; 3 - Middle Triassic limestone and dolomites; 4 - Palaeozoic impermeable rocks (mostly Permian); 5 - extent of the hydraulic depression cone in Triassic carbonates; 6 - main faults

Geological and hydrogeological setting and karstification of the Olkusz area

The karst of the eastern Silesian Upland is developed in carbonate rocks of Middle Triassic (Mushelkalk) and Upper Jurassic age (*Fig. 1*). The principal features of the

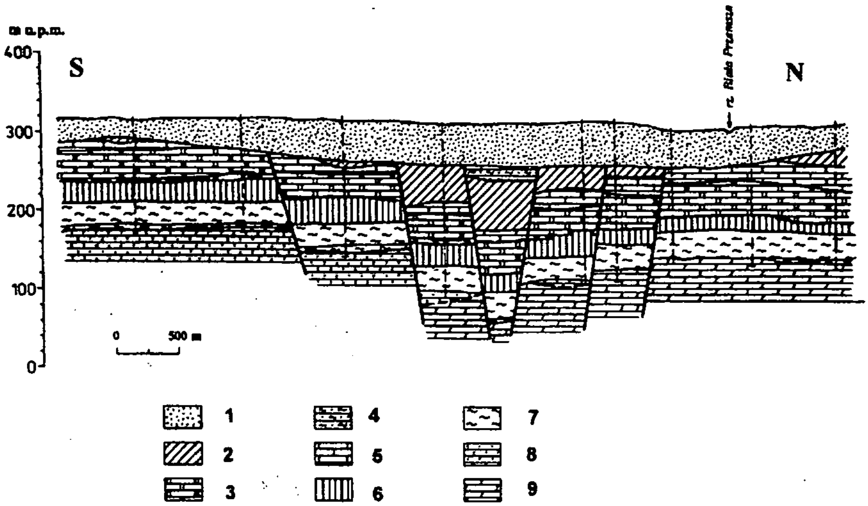

Fig. 2 Longitudinal geological cross section of the central area of the Bledow Desert
1 - sands and clays (Quaternary); 2 - shales and mudstones (Upper Triassic); 3 - ore bearing dolomites (Middle Triassic); 4 - marls and limestone (Jurassic); 5 - marly and diplopora dolomites (Middle Triassic); 6 - limestone, dolomites and marls (Middle Triassic); 7 - dolomites and marls (Lower Triassic); 8 - conglomerates, sandstone and mudstones (Permian); 9 - limestone, dolomites and sandstone (Devonian).

geology of the Olkusz area are shown on *Fig. 2*. Folded Palaeozoic rocks lie at the massif's base. The main mass of the geological profile consists of a monoclinal structure of Mesozoic rocks, principally Triassic carbonates. The whole structure is covered with thick Quaternary sandy-clay sediments. The origin and age of these sediments are not well defined. After sedimentological data they should be fluvio-glacial, proluvial-fluvial and in places proluvial-deluvial deposits (*Szczypek, Wach 1989*). The superficial sands are bedded, fine- and medium-grained. The mean thickness of sandy-clay sediments varies between 10 and 20 m. In meridional palaeovalley of Biala Przemsza river, situated in the centre of the area, the thickness reaches 45-60 m.

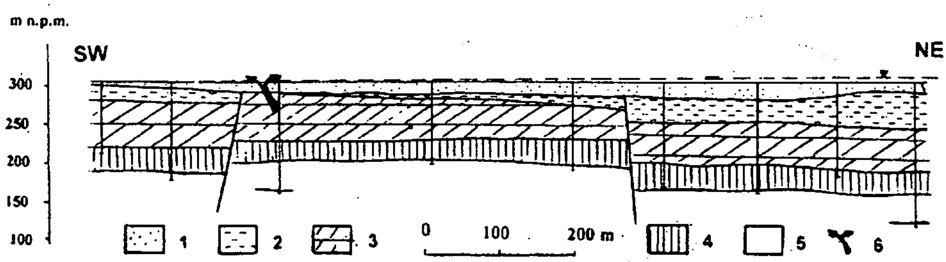

Fig. 3 Geological cross section in the vicinity of the travertine dome in Laski.
Groundwater level according to 1958 data.
1- Quaternary sediments; 2- Upper Triassic shales; 3- Middle Triassic diplopora and ore bearing dolomites; 4- Roethian dolomites and marls; 5- Permian sandstone; 6- hydrogeological window and place of ascend outflow of groundwater in artesian condition (location of travertine dome).

The base of the karst-fissured system consists of Permian-Lower Triassic sedimentary rocks. By tectonic and sedimentary boundaries, Middle Triassic limestones and dolomites are in hydraulic contact with the underlying karstified Devonian rocks (*Motyka 1988; Rozkowski, Wilk 1980*) (*Fig. 2*). Tectonic model of the Olkusz area is complex. The main mass of carbonates and impermeable layers are divided into small tectonic units by faults and parallel horsts and grabens. Polygenetic and polycyclic systems of buried karst, with traces of paleokarst, established in early phases of regional karstification, are divided and separated by impermeable fault zones. Occurrence of impermeable sediments of Upper Triassic in the top layer of Triassic carbonates determine semi-confined, partly artesian karst-fissured type of the aquifer (*Fig. 2*). In zones of impermeable layer discontinuity hydraulic connection between karstified Middle Triassic rocks and Pleistocene sandy cover occur (*Motyka 1988; Tyc 1997*) (*Fig. 3*). Under natural

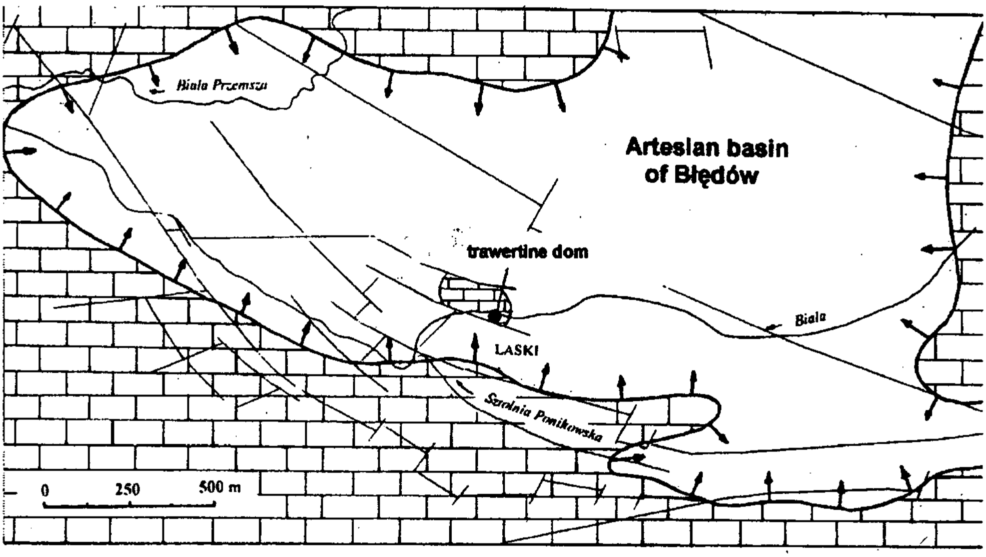

Fig. 4 Geological situation and location of the hydrogeological window and travertine dome in Laski. Area with arrows shows the extent of the local artesian basin within the Triassic carbonates rocks.

conditions karst water recharges sandy sediments and outflows by ascending springs to river valleys. As a result, travertine deposition occurred in such places surrounded by aeolian sands. The travertine dome in Laski is a good example of this phenomenon (*Fig. 4, Photo 1*) (*Gradzinski et al. 1999*). Exploitation of the lead-zinc deposits and groundwater for water supply caused the development of a 350 km^2 cone of depression. The pumping rate for the area is c. 380 m^3/min (6.3 m^3/s). The base of the induced drawdown lies below most of the open and filled karst features. Contemporary artificial drainage is connected with a pre-Quaternary system of karst water circulation (*Tyc 1997, 1999*). As a result of mining within the Triassic carbonate aquifer, new hydraulic components have appeared; artificial water galleries that take over the role of master conduits in the functioning of the karst circulation. Most of the ascending karst springs in the area of Bledow Desert have disappeared and some changed their role to function as ponors recharging the aquifer with polluted surface water. All these hydrogeological changes have impacts on the karst-aeolian ecosystem.

Photo 1 Travertine dome with cave in Laski (for the location see *Fig. 4*). (photo. *A. Tyc*)

Origin of the artificial desert near Olkusz

The climate of Poland, with mean annual precipitation of 600-700 mm, is not favourable to desert or semi-desert environments. Despite the common occurrence of sandy areas across the whole country, mainly of fluvio-glacial origin, the climatic conditions are such that they are covered with vegetation, mainly with pine forests. So, there are no natural sandy deserts in the eastern Silesian Upland and Olkusz area. The sand cover is due to human activity. Archaeological and historical data indicate that Bledow Desert is a result of deforestation during ancient exploitation of lead and silver ores. Ancient exploitation in the Olkusz area and in other parts of eastern Silesian Upland began in the first millennium AD. The first shallow mines and metallurgic works were situated on hills of the Triassic ore-bearing dolomites, in conditions of bare rock outcrops. The beginning of the intensive exploitation and metallurgy of lead and silver is dated for 13th century. Medieval deforestation was the main factor influencing development of an anthropogenic sandy desert over the karst system in the Olkusz area. In the period of strong development of extractive industry the surrounding forests were the main fuel source for the developing mining and metallurgy. Therefore, the Bledow Desert area was completely deforested. Transportation or accessibility of ores was not the main technical problem of the early exploitation. A serious problem was the dewatering system. Due to water inflow, development of exploitation by underground mining was difficult and several phases of mining can be distinguish in its history. The rise and fall of mineral exploitation over time were followed by complete deforestation and reforestation of the Bledow Desert. After Medieval deforestation, the 16th and 17th centuries saw a second period of intensive wood cutting and degradation of forest in the area. Wood was used for charcoal production and for construction of underground and surface drainage canals. Oak and beach trees were mainly used for construction. In that period, local artificial drainage was accompanied by total destruction of the ecosystem, except the unique karst springs floristic associations (*Rahmonow 1999*). Intensive exploitation of wood in the late 16th century resulted in supply difficulties. In that period mines and metallurgical works imported wood from other regions. The reforestation process followed the introduction of coal as fuel for industry in the 19th century. In addition to large scale dewatering of the karst-fissured aquifer and a chain of human induced changes in the karst-aeolian environment due to contemporary lead and zinc ores exploitation, spontaneous regeneration of forest ecosystems is recorded. Comparison of forest in the early 19th century and at the present shows that in the Olkusz area and Bledow Desert forest terrains increased in surface area. However, utilisation of Bledow Desert as an army polygon for several tens of years (mainly during and just after World War II) and large fire in the early 1990s interrupted spontaneous reforestation.

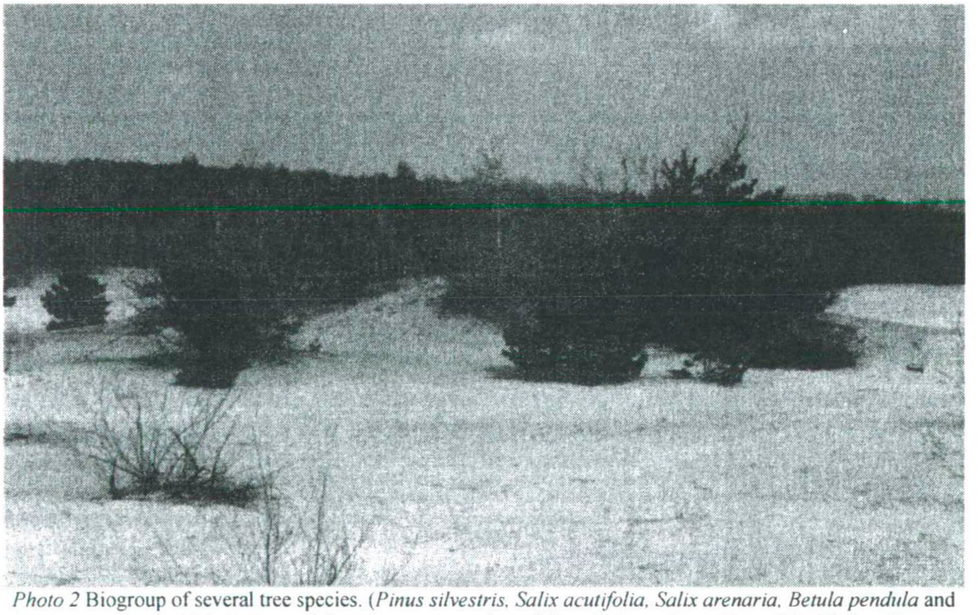

Photo 2 Biogroup of several tree species. (*Pinus silvestris, Salix acutifolia, Salix arenaria, Betula pendula* and *Juniperus communis*) Late stage of the primary succession of flora during reforestation of the Bledow Desert. (photo. *A. Tyc*)

Spontaneous reforestation of the artificial desert

Until recently, the Desert of Bledow formed part of one of the largest inland areas of blown sands in Central Europe. All the time river valleys, Biala valley in the central part of the desert predominantly, were the place of specific flora associations within the area.

Artesian conditions give in several sites possibilities to establish karst springs with cold water overflowing on the sandy deposits (*Fig. 3 and 4*). It was very characteristic that before artificial dewatering in the 1970s endemic (e.g. *Cochlearia polonica*) and relict (e.g. arctic species of *Scorpidium furgescens*) flora species, as well as mountainous species of vascular flora (*Michalik, 1979*) were found in such springs. In that period the area of blown sands covered more than 12 km^2 in the central part of the present Bledow Desert. Bare sands and deflation fields were common phenomena. It was in marked contrast to surrounding environments. In the early 1970s, the Olkusz region began to be influenced by large scale dewatering of the lead-zinc mines (see *Fig. 1*). In spite of this, the process of reforestation intensified. Sand areas are presently rare and are generally covered with bushes, sods or even woods. In contrast, the very rich floristic associations with overflowing karst water in the valley bottoms were destroyed by dewatering.

Understanding reforestation processes and their future effects on karst-aeolian ecosystems is one of the most important tasks for nature protection in eastern Silesian Upland. Different stages of plant succession have been observed and recorded on selected transects through the Bledow Desert. Phytosociological, ecological and soil investigations were conducted in order to find the regularity of plant succession and link them with the soil and hydrological processes. On the transects, the presence of 16 plant associations (3 forest assemblages) as well as 6 plant communities with undefined phytosociological range has been recorded. From an ecological point of view all plants have adapted to live in warm, dry, full lighted habitats deficient in organic mater (*Czylok et al. 1998; Rahmonow 1999*). Ability to change is one of the most characteristic features of biocenose. Irreversible directive tendency to changes of floristic associations is called succession. It is possible to state that the regeneration and reforestation of the Bledow Desert realised by means of succession. Moreover, two types of succession – primary and secondary – have been distinguished in the transects. The primary succession consists of the following stages: (1) encroachment of plants, (2) sodding, (3) bushes, (4) biogroup formation and (5) afforestation. The secondary succession proceeds after similar schema of stages but on sands rich in organic mater. Wind and animals play an important role in plant succession by spreading new species from the surrounding areas. Very important is the artificial overgrowing of the borders of the Bledow Desert by *Elymus arenarius*, *Salix arenaria* and *Salix acutifolia*, which are not native to the Silesian Upland. Plant succession is a common phenomena in sandy areas of Poland, deforested by human activity, but in the Bledow Desert there are two stages of succession that are unknown elsewhere, the participation of algae in the first stage of succession and a stage of biogroup. Special attention has to be paid to the role of several species biogroups (*Pinus sylvestris, Salix acutifolia, Salix arenaria, Betula pendula and Juniperus communis*) in the processes of overgrowing the Bledow Desert (*Photo 2*). Following afforestation, soil profiles are developing. Fossil soils detected in sand profile mark several stages of plant succession and afforestation of the area in the past.

Conclusions

The phenomena and processes presented in the paper show how management and protection of intensively transformed and impacted karst terrains presents complex and difficult problems. The coincidence of karst and aeolian ecosystems in the eastern part of the Silesian Upland results in very specific relations between these two very different environments. Many centuries of management and changes of natural structure in these ecosystems have created new relations and plant associations, often unknown in natural conditions. In the particular example of the Bledow Desert, such relations were created between covered and buried karst systems that have been strongly transformed by ore exploitation and aeolian sand environments strongly affected by repeated phases of deforestation and reforestation. Research and registration of the contemporary transformation processes, mainly plant succession, are very important in the context of contemporary mining industry closure in the eastern Silesian Upland and the slow restoration of hydrogeological conditions from the period before artificial drainage in the karst aquifer. In future, karst waters will again be able to recharge sandy areas of the Bledow Desert.

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